Phase-Controlled Magnetic Mirror for Wavefront Correction

Goddard Space Flight Center, Greenbelt, Maryland

Typically, light interacts with matter via the electric field and interaction with weakly bound electrons. In a magnetic mirror, a patterned nanowire is fabricated over a metallic layer with a dielectric layer in between. Oscillation of the electrons in the nanowires in response to the magnetic field of incident photons causes a re-emission of photons and operation as a "magnetic mirror." By controlling the index of refraction in the dielectric layer using a local applied voltage, the phase of the emitted radiation can be controlled. This allows electrical modification of the reflected wavefront, resulting in a deformable mirror that can be used for wavefront control.

Certain applications require wavefront quality in the few-nanometer regime, which is a major challenge for optical fabrication and alignment of mirrors or lenses. The use of a deformable magnetic mirror allows for a device with no moving parts that can modify the phase of incident light over many spatial scales, potentially with higher resolution than current approaches. Current deformable mirrors modify the incident wavefront by using nano-actuation of a substrate to physically bend the mirror to a desired shape.

The purpose of the innovation is to modify the incident wavefront for the purpose of correction of fabrication and alignment-induced wavefront errors at the system level. The advanced degree of precision required for some applications such as gravity wave detection (LISA — Laser Interferometer Space Antenna) or planet finding (FKSI — Fourier-Kelvin Stellar Interfswerometer) requires wavefront control at the limits of the current state of the art.

All the steps required to fabricate a magnetic mirror have been demonstrated. The modification is to apply a bias voltage to the dielectric layer so as to change the index of refraction and modify the phase of the reflected radiation. Light is reflected off the device and collected by a phase-sensing interferometer. The interferometer determines the initial wavefront of the device and fore optics. A wavefront correction is calculated, and voltage profile for each nanowire strip is determined. The voltage is applied, modifying the local index of refraction of the dielectric under the nanowire strip. This modifies the phase of the reflected light to allow wavefront correction.

This work was done by John Hagopian and Edward Wollack of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16008-1

Frame-Transfer Gating Raman Spectroscopy for Time-Resolved Multiscalar Combustion Diagnostics

This invention could potentially benefit the development of advanced combustion systems such as gas turbine engines and internal combustion engines.

John H. Glenn Research Center, Cleveland, Ohio

Accurate experimental measurement of spatially and temporally resolved variations in chemical composition (species concentrations) and temperature in turbulent flames is vital for characterizing the complex phenomena occurring in most practical combustion systems. These diagnostic measurements are called multiscalar because they are capable of acquiring multiple scalar quantities simultaneously. Multiscalar diagnostics also play a critical role in the area of computational code validation. In order to improve the design of combustion devices, computational codes for modeling turbulent combustion are often used to speed up and optimize the development process. The experimental validation of these codes is a critical step in accepting their predictions for engine performance in the absence of cost-prohibitive testing.

One of the most critical aspects of setting up a time-resolved stimulated Raman scattering (SRS) diagnostic system is the temporal optical gating scheme. A short optical gate is necessary in order for weak SRS signals to be detected with a good signal-to-noise ratio (SNR) in the presence of strong background optical emissions. This time-synchronized optical gating is a classical problem even to other spectroscopic techniques such as laser-induced fluorescence (LIF) or laser-induced breakdown spectroscopy (LIBS). Traditionally, experimenters have had basically two options for gating: (1) an electronic means of gating using an image intensifier before the charge-coupled-device (CCD), or (2) a mechanical optical shutter (a rotary chopper/mechanical shutter combination).

A new diagnostic technology has been developed at the NASA Glenn Research Center that utilizes a frame-transfer CCD sensor, in conjunction with a pulsed laser and multiplex optical fiber collection, to realize time-resolved Raman spectroscopy of turbulent flames that is free from optical background noise (interference). The technology permits not only shorter temporal optical gating (down to <1 μs, in principle), but also higher optical throughput, thus resulting in a substantial increase in measurement SNR.

The new technology is an experimental method (or scheme) for isolating true Raman spectral signals from flames using a single CCD detector. It does not use an image intensifier or a mechanical shutter. Individual electrical or optical devices employed in this method are not new; however, the diagnostic methodology itself, which utilizes a combination of existing devices for a particular application, is a novel concept.

The present methodology employs two key optical devices: a pulsed laser (nanosecond pulses) and a frame-transfer CCD sensor. Frame-transfer CCD sensors have been historically used to capture fast (microsecond timescale) transient events, such as Bose-Einstein condensate phenomena, over a short period of time (milliseconds). By their operation, the sensor area is exposed for a certain time and the charge is then transferred to the frame transfer area (or masking area) row-by-row, and is read out via a gain register or serial register. This is called “frame-transfer” readout or “kinetics” readout. The use of frame-transfer readout provides a very effective way of isolating true Raman signals from laser-generated optical interferences in any combustion environment, in principle, without having to employ multiple CCD detectors or polarizer on the detection side.

Since laser-induced background emissions are unpolarized, unlike Raman scattering, which is polarized, they can be selectively isolated (and subtracted). While the theory of this polarization technique has been proposed previously, the implementation of this technique for time-resolved Raman diagnostics has not been matured. A principal reason is that an enabling technology that can increase the SNR was needed. When a flame receives two orthogonally polarized, but otherwise identical, laser pulses, Raman scattering can be observable only for the vertically polarized excitation pulse. The (unpolarized) laser-generated background emissions are observed regardless of the polarization state of the excitation pulses. If the two orthogonally-polarized laser pulses are separated in time so that they just fall onto a pair of consecutive sub-frames on the CCD sensor, subtracting the one (laser-generated background emission only) from the other (Raman signal plus background emission) results in a true Raman spectrum.

This work was done by Quang-Viet Nguyen, David G. Fischer, and Jun Kojima of Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18483-1.

Thermal Properties of Microstrain Gauges Used for Protection of Lithium-Ion Cells of Different Designs

Commercial uses include lithium-ion batteries used in a human-rated environment, such as in automobile applications.

Lyndon B. Johnson Space Center, Houston, Texas

The purpose of this innovation is to use microstrain gauges to monitor minute changes in temperature along with material properties of the metal cans and pouches used in the construction of lithium-ion cells. The sensitivity of the microstrain gauges to extremely small changes in temperatures internal to the cells makes them a valuable asset in controlling the hazards in lithium-ion cells. The test program on lithium-ion cells included various cell configurations, including the pouch type configurations.

The thermal properties of microstrain gauges have been found to contribute significantly as safety monitors in lithium-ion cells that are designed even with hard metal cases. Although the metal cans do not undergo changes in material property, even under worst-case unsafe conditions, the small changes in thermal properties observed during charge and discharge of the cell provide an observable change in resistance of the strain gauge. Under abusive or unsafe conditions, the change in the resistance is large. This large change is observed as a significant change in slope, and this can be used to prevent cells from going into a thermal runaway condition. For flexible metal cans or pouch-type lithium-ion cells, combinations of changes in material properties along with thermal changes can be used as an indication for the initiation of an unsafe condition.

Lithium-ion cells have a very high energy density, no memory effect, and almost 100-percent efficiency of charge and discharge. However, due to the presence of a flammable electrolyte, along with the very high energy density and the capability of releasing oxygen from the cathode, these cells can go into a hazardous condition of venting, fire, and thermal runaway. Commercial lithium-ion cells have current and voltage monitoring devices that are used to control the charge and discharge of the batteries. Some lithium-ion cells have internal protective devices, but when used in multi-cell configurations, these protective devices either do not protect or are themselves a hazard to the cell due to their limitations. These devices do not help in cases where the cells develop high impedance that suddenly causes them to go into a thermal runaway condition. Temperature monitoring typically helps with tracking the performance of a battery. But normal thermistors or thermal sensors do not provide the accuracy needed for this and cannot track a change in internal cell temperatures until it is too late to stop a thermal runaway.

The microstrain gauges under study have shown remarkable changes in resistance with changes in temperature that show a very close tracking to the current used to charge and discharge the lithium-ion cells. As the cells are charged, there is a very slight increase in temperature at the end of charge, and the same during the discharge process. Although normal thermistors do not show a big change in temperature, the strain gauges have been able to track with great accuracy the thermal changes in the cells during these processes. Although strain gauges have been used to track pressures internal to cells in battery chemistries that use pressure vessels such as the Ni-hydrogen cells, they have not been used to track resistance changes due to temperatures. Existing thermal sensors do not have the sensitivity to be able to track small changes in internal temperatures of the cells, so monitoring systems cannot detect changes fast enough to be able to provide any protection. With lithium-ion cells, when the thermal sensors